



# The combination effect of adding rosemary extract and oregano essential oil on ground chicken meat quality

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## Abstract

Preservative effect of oregano essential oil (OE) and rosemary extract (RE) on ground chicken meat stored at different refrigeration time had been evaluated. Six treatments were prepared: T1) Control (No additives); T2) Combination (CM<sub>1</sub>) of 100 ppm OE and 300 ppm RE; T3) CM<sub>2</sub>: 100 ppm OE + 350 ppm RE; T4) CM<sub>3</sub>: 150 ppm OE + 300 ppm RE; T5) CM<sub>4</sub>: 150 ppm OE + 350 ppm RE; T6) 14 ppm of *butylated hydroxyanisole* (BHA). Meat patties were individually packaged in oxygen-permeable bags stored at 4 °C, and analyzed for lipid and protein oxidation, and CIE color values at 0, 4, and 7 days. Individual cooked thigh meats were used to evaluate different sensory attributes. All additives showed significant ( $P < 0.05$ ) antioxidant effect delaying lipid and protein oxidation after day 4 comparing to the control treatment samples. However, the highest significant ( $P < 0.05$ ) effect among all treatments was by CM<sub>4</sub>. The CM<sub>4</sub> was the highest stabilizing raw meat color, and preventing meat discoloration. In addition, it showed (CM<sub>4</sub>) highest overall acceptability scores values regarding sensory evaluation. Based on current results, both OE and RE had a potential antioxidant activity; however, this could be stronger if used together.

**Keywords:** oregano essential oil; rosemary extract; protein oxidation; lipid oxidation; ground meat.

**Practical Application:** Improving ground meat shelf-life and their quality using combined natural plants extracts.

## 1 Introduction

Recently, in food safety and preservation sector it becomes highly recommended to avoid using synthetic antioxidant (Taghvaei & Jafari, 2015; Pereira et al., 2017; Fruet et al., 2020). Food scientist were extensively investigated this by testing many natural replacements (Candan & Bagdatli, 2017; Pereira et al., 2017; Aminzare et al., 2019). Currently, synthetic antioxidants (SA) such as *butylatedhydroxyanisole* (BHA), *butylatedhydroxytoluene* (BHT), *Tertiary butyl hydroquinone* (TBHQ), are widely used in food containing oil such as meat products (Monahan & Troy, 1997; Race, 2009). In addition, several commercial meat preservatives also used in the meat industry such as sodium nitrite/nitrate, and potassium nitrite which consider very essential to maintain their color and flavor (Al-Shuib & Al-Abdullah, 2002; Decker et al., 2010). However, using these additives frequently in human food may cause possible carcinogenic and toxicological effect (Altmann et al., 1986; Kahl & Kappus, 1993; Kumar et al., 2015; Fruet et al., 2020). This approach of using natural sources has been growing up rapidly to be used as new meat preservation technology (Shah et al., 2014; Kumar et al., 2015; Manassis et al., 2020). This also connected with the increase in consumer's demands on both natural and organic food in the last two decades (Jensen et al., 2011; Velasco & Williams, 2011; Pereira et al., 2017). However, it reported that using one natural preservative alone is not effective as the synthetic (commercial) antioxidant (Brewer, 2011; Kumar et al., 2015). Thus, researchers recommended adding these supplements in the form of combination, which may improve their action (Honikel, 2008; Smet et al., 2008; Brewer, 2011; Oostindjer et al., 2014; Hwang et al., 2014). However,

researchers still need to investigate their effective level, how it interact in meat system. Rosemary extract and (OE) is one of the most popular natural additives have been tested in different food recently (Liu et al., 2009; Haile, 2015; Pereira et al., 2017; Al-Hijazeen, 2018). These medical plants extracts were evaluated directly through meat surface as (Velasco & Williams, 2011; Kumar et al., 2015; Zhai et al., 2018), mixing in ground meat (Ahn et al., 2007; Al-Hijazeen, 2014; Al-Hijazeen et al., 2016a, b; Zahid et al., 2018; Manassis et al., 2020), indirectly in the animal feed (Botsoglou et al., 2003; Ri et al., 2017; Sierżant et al., 2018; Cázares-Gallegos et al., 2019), and it mostly showed positive effect enhancing meat quality and extended their shelf-life.

In Jordan, these extracts are widely available in the local market (at *low concentration*) which applies for different purposes, such as food flavor, pharmaceutical uses, and human health etc (Oran & Al-Eisawi, 1998; Ibrahim et al., 2012). However, *Origanum syriacum L.* and *Rosmarinus officinalis Linn.* extract (Grown under Jordanian Climate conditions) were characterized with a high level of phenolic compounds (Ibrahim et al., 2012; Hudaib et al., 2015; Al-Hijazeen, 2018; Al-Hijazeen & Al-Rawashdeh, 2019). Generally, the antioxidant effect of these plants extracts are based on their phenolic compounds (Brewer, 2011; Shah et al., 2014). For instance, antioxidant activity of oregano oil linked with their carvacrol and thymol (78-82%) and the other polyphenolic constituents (Adam et al., 1998; Yanishlieva et al., 1999; Al-Hijazeen, 2018). In addition, they are main components giving their antimicrobial effect against several food borne diseases (Ultee et al., 2002; Nostro et al., 2004, 2007;

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Ahn et al., 2007). Chouliara et al. (2007) found an improvement on chicken meat freshness, shelf life, and decreasing of their microbes (lactic acid bacteria, TVC, pseudomonas spp., yeast) by direct adding oregano essential oil. Rosemary extract had been analyzed of their phenolic constituent's, and it found that carnosic acid, carnosol, rosmanol, rosmariquinone and rosmaridiphenol, ursolic acid, and caffeic acid (Aruoma et al., 1992; Basaga et al., 1997) are causing their antioxidant and antimicrobial activities. In addition, RE had been documented to have anti-inflammatory, anti-diabetic and anti-cancer activities (Moreno et al., 2006; Khalil et al., 2012; Moore et al., 2016). Ninety percent of RE antioxidant properties is originated from both carnosic and carnosol constituent's (Aruoma et al., 1992; Erkan et al., 2008). However, the suitable level of RE that should be use in meat system is still under investigation and affected by several factors (Al-Hijazeen & Al-Rawashdeh, 2019; Duoxia et al., 2020). Furthermore, there were no research study investigate the combination effect of *Rosmarinus officinalis* Linn. extract and *Origanum syriacum* L. essential oil (grown in Jordan), and their level, on ground chicken meat. In addition, this combination may have synergistic effect preventing rancidity development and improve meat shelf life. The objectives of current research were: 1) to evaluate the effect of adding different combination of RE and OE on broiler meat quality; 2) compare their effect with the synthetic antioxidant BHA; 3) determine the best combination level that could be use in the meat industry.

## 2 Materials and methods

### 2.1 Meat preparation

All meat were deboned, cleaned, and stored as described by Al-Hijazeen & Al-Rawashdeh (2019). Chicken thigh meat was purchased from a local slaughtering plant and ground (twice) a through a 8-mm plate then a 3-mm plate (*Moulinex*, Type *DKA1*, France). Prepared treatments were including: T1) Control (No additives); T2) Combination ( $CM_1$ ) of 100 ppm OE and 300 ppm RE; T3)  $CM_2$ : 100 ppm OE + 350 ppm RE; T4)  $CM_3$ : 150 ppm OE + 300 ppm RE; T5)  $CM_4$ : 150 ppm OE + 350 ppm RE; T6) 14 ppm of *butylated hydroxyanisole* (BHA). Oregano essential oil (OE) and RE concentration were chosen based on several preliminary and original meat quality studies considering their antioxidant activities (Al-Hijazeen & Al-Rawashdeh, 2019; Al-Hijazeen, 2018). Oregano essential oil (*Origanum syriacum* L.) was purchased from a certified company (*Green Fields Factory for oils*, Amman/Jordan) using the most efficient purification, extraction, and steam distillation methods. The HPLC analysis (Royal Scientific Society, Jordan, Amman research institution (RSS)) of the OE showed that 76.39% of the essential oil was *carvacrol*. Rosemary extract (Extracted from cultivated rosemary in Jordan) was obtained from the same source, and the HPLC analysis (RSS) of the RE was measured as described by the method of Okamura et al. (1994), and it was containing  $26 \pm 3\%$  as the average of phenolic diterpenes (4% carnosol and 6% carnosic acid and other phenolic constituents). The BHA powder, RE, and OE were dissolved in 10 mL of 100% ethanol, and then mixed with 50 mL mineral oil (Sant Cruz Biotechnology, Dallas, TX, USA) to prepare their stock solution. The ethanol mixed with mineral oil was

split out using a rotary evaporator (Heidolph, Model Laborota 4001-efficient) at (70 °C, 175 mbar vacuum pressure) before adding the stock to the meat mixture. All supplements were added to the ground meat, and then mixed for 4 min in a bowl mixer individually. However, they were supplemented using same quantity of mineral oil to get the same experimental conditions. The individual prepared meat patties (approximately 100 g each/4 replicate of each treatment) were packaged in oxygen-permeable bags (polyethylene, Size: 11 × 25 cm, *Future for Plastic Industry, Al-Mountaz bags*, Co. L.T.D, Jordan), stored at 4 °C cooler for up to 7 days, and analyzed for lipid and protein oxidation, and CIE color values at 0, 4, and 7 days. In the cooked section, the raw meat samples were first packaged in oxygen impermeable vacuum bags (Albalabki-Jordan, Malcom SRL, Milano, Italy), and the meat were cooked in-bag in a 90 °C water bath (Memmert, WNB 14; *GmbH + Co. KH, D-91107 Schwabach*, Germany) until the internal temperature of the meat patties reached to 75 °C. After cooling to room temperature, meat samples (cooked) was transferred to a new oxygen-permeable bag (polyethylene, Size: 11 × 25 cm, *Future for Plastic Industry, Al-Mountaz bags*, Co. L.T.D, Amman, Jordan), and stored at 4 °C for up to 7 days to be analyzed for quality parameters. Same preparation method was done for all sensory analysis treatments samples. However, the ground (raw) meat patties stored at 4 °C up to 4 days before cooking and for each evaluation session.

### 2.2 Color measurement

In the meat lab (Department of Animal Production); Konica Minolta Meter (CR-400, Konioca Minolta, Osaka, Japan) was used to measure meat color. The colorimeter was calibrated using an illuminant source C (Average day light) on a standard ceramic tile enveloped with the same plastic bag used for meat samples. The color values were expressed as CIE  $L^*$ - (lightness),  $a^*$ - (redness), and  $b^*$ - (yellowness) values (American Meat Science Association, 2012). The un-uniform (defects) color area where excluded from the targeted measurements. An average of two random readings on the top of the sample surface was used for statistical analysis.

### 2.3 Thiobarbituric acid-reactive substances (TBARS) measurement

Lipid oxidation in ground meat sample was determined using a TBARS method (Ahn et al., 1998) with minor modification as described by Al-Hijazeen et al. (2016a). All chemicals, stock solution, and equipment were prepared before starting chemical analysis. The TBARS number was expressed as mg of malondialdehyde (MDA) per kg of meat.

### 2.4 Protein oxidation

Protein oxidation (DNPH: *2,4-Dinitrophenylhydrazine*) values was estimated using the general method of total carbonyl value described by Lund et al. (2008) and as reported and modified by Al-Hijazeen (2018). The carbonyl content was calculated as nmol/mg protein using absorption coefficient of 22,000/M/cm as described by Levine et al. (1994).

## 2.5 Sensory panel evaluation

Highly trained sensory panels (10 panelists) were used to evaluate certain sensory attributes of the ground chicken (*cooked thigh*) meat similarly (Same procedure, scale, and preparation method for all attributes used) as described by Al-Hijazeen & Al-Rawashdeh (2019).

## 2.6 Statistical analysis

Data were analyzed using the procedures of generalized linear model (Proc. GLM, SAS program, version 9.3, 2012). Mean values and standard error of the means (SEM) were reported (SAS Institute, 2012). The significance was defined at  $P < 0.05$  and Tukey test or Tukey's Multiple Range test were used to determine the significant differences between the mean values.

## 3 Results and discussion

Generally, both RE and OE have no significant effect on the ultimate pH of raw meat, and cooking loss %, as it reported in previous studies (Al-Hijazeen & Al-Rawashdeh, 2019; Al-Hijazeen, 2019). This enhance the univariate analysis between treatments especially lipid and protein oxidation measurements. Therefore, any treatments variation in this study will be due to treatments additive effect. In addition, current study is a part of meat quality and safety evaluation project (GN: 120/14/118) which designed to evaluate both OE and RE antioxidant/ antimicrobial effect using ground chicken meat.

### 3.1 Lipid oxidation

Among all treatments tested by TBARS method (Ahn et al., 1998) there were no significant differences ( $P > 0.05$ ) at day 0 for both raw and cooked meat mean values. However, all treatments additives showed significant antioxidant effect ( $P < 0.05$ ) compared to the control samples after day 4 (Table 1). This was in agreement with previous studies (Liu et al., 2009; Kahraman et al., 2015; Al-Hijazeen et al., 2016a; Al-Hijazeen & Al-Rawashdeh, 2019; Al-Hijazeen, 2019), tested different level of OE and RE using ground chicken meat. In addition, the effect of adding OE was positively extends chicken meat shelf life, decrease off-odor

flavor, and delay rancidity development (Chouliara et al., 2007; Fasseas et al., 2008; Kumar et al., 2015; Manassis et al., 2020).

Cooking increase lipid oxidation (primary and secondary products) by disrupting cell membranes, and releasing more pro-oxidants (Ahn & Lee, 2002; Sampaio et al., 2012). Thus, the variation among cooked meat treatments is obvious and more significant compared to the raw meat (Ahn et al., 2009; Al-Hijazeen et al., 2016a). Usually, cooking denatured the antioxidant enzymes, releasing the free iron to extracellular fluid, disrupt phospholipid bi-layer in cells membrane which make internal cell more susceptible for oxygen and catalysts (Gray et al., 1996; Ahn & Lee, 2002). As in current study, there were no significant differences ( $P > 0.05$ ) appeared between all additives at day 4 and 7 of storage time using raw thigh meat. On the other hand, CM<sub>3</sub> and CM<sub>4</sub> was showed the highest significant ( $P < 0.05$ ) effect decreasing malonaldehyde formation in the meat samples. This may be due their high concentration (%) of both extract compared to other treatments. All combination treatments were showed higher significant ( $P < 0.05$ ) effect compared to the synthetic antioxidant (BHA) at day 7 using cooked meat samples. However, synthetic BHA effect usually enhanced by adding another secondary (synergistic) antioxidant which should be considers later (Rowe et al., 2009; Sonam & Guleria, 2017). This agreed with the several research studies which suggested that adding natural antioxidants in combination could be competitive to the effect of using synthetic additives (Honikel, 2008; Smet et al., 2008; Brewer, 2011; Oostindjer et al., 2014; Hwang et al., 2014; Sonam & Guleria, 2017). However, even the synergistic effect was not achieved, it was concluded that adding both OE and RE in combination (additive effect) will be better than using them separately. This antioxidant activity of these plant extract linked with the high content of poly phenolic compound (Brewer, 2011; Kumar et al., 2015). Both OE and RE contain many phenolic compounds (*carvacrol and thymol; carnosic and carnosol*) decrease rancidity development and enhance chicken meat reducing capacity (Al-Hijazeen, 2018; Al-Hijazeen & Al-Rawashdeh, 2019). The CM<sub>4</sub> treatment showed the lowest TBARS values at day 7 using both raw and cooked meat. Finally, there was a questionable variation between many research studies evaluating RE and OE of their recommended level (Sebranek et al., 2005; Kahraman et al., 2015; Alhijazeen et al., 2016a; Al-Hijazeen & Al-Rawashdeh, 2019; Al-Hijazeen, 2019).

**Table 1.** \*TBARS values of ground thigh meat at different storage time at 4 °C.

Time	Control	CM <sub>1</sub>	CM <sub>2</sub>	CM <sub>3</sub>	CM <sub>4</sub>	BHA	SEM
----- TBARS (mg/kg)meat -----							
<b>Raw meat</b>							
Day 0	0.24 <sup>az</sup>	0.21 <sup>ay</sup>	0.22 <sup>ay</sup>	0.23 <sup>ay</sup>	0.21 <sup>ay</sup>	0.22 <sup>az</sup>	0.018
Day 4	1.24 <sup>ay</sup>	0.32 <sup>by</sup>	0.27 <sup>by</sup>	0.24 <sup>by</sup>	0.23 <sup>by</sup>	0.33 <sup>by</sup>	0.035
Day 7	2.60 <sup>ax</sup>	0.99 <sup>bx</sup>	0.75 <sup>bx</sup>	0.73 <sup>bx</sup>	0.67 <sup>bx</sup>	0.96 <sup>bx</sup>	0.086
SEM	0.56	0.032	0.067	0.07	0.063	0.02	
<b>Cooked meat</b>							
Day 0	1.11 <sup>az</sup>	1.06 <sup>az</sup>	1.10 <sup>ay</sup>	1.09 <sup>ay</sup>	0.98 <sup>ay</sup>	1.18 <sup>az</sup>	0.β-093
Day 4	3.21 <sup>ay</sup>	1.32 <sup>cy</sup>	1.27 <sup>cy</sup>	1.13 <sup>cy</sup>	1.06 <sup>cy</sup>	1.77 <sup>by</sup>	0.070
Day 7	7.19 <sup>ax</sup>	2.20 <sup>ex</sup>	2.06 <sup>cdx</sup>	1.70 <sup>dex</sup>	1.45 <sup>ex</sup>	2.68 <sup>bx</sup>	0.092
SEM	0.118	0.04	0.099	0.088	0.067	0.088	

\*TBARS value in mg malonaldehyde/kg meat. Treatments: Control (No additives); CM<sub>1</sub>:100 OE and 300 RE; CM<sub>2</sub>:100 OE + 350 RE; CM<sub>3</sub>:150 OE + 300 RE; CM<sub>4</sub>: 150 OE + 350 RE; BHA: 14 ppm of *butylatedhydroxyanisole*; SEM: Standard error of the means. <sup>a-c</sup>Value with different letters within a row are significantly different ( $P < 0.05$ ). n=4. <sup>x-z</sup>Value with different letters within a column are significantly different ( $P < 0.05$ ).

### 3.2 Protein oxidation

This study was using chicken thigh meat instead of breast meat since it contain more fat and myoglobin causing more significant variation between treatments (Ahn et al., 2009; Al-Hijazeen, 2019). Among all treatments, there were no significant differences ( $P > 0.05$ ) between total carbonyl mean values at day 0 for both raw and cooked meat samples (Table 2).

This may be due to the low amount of total carbonyl formed when evaluating raw meat as reported by Al-Hijazeen (2018) and Al-Hijazeen & Al-Rawashdeh (2019). Similar findings were reported by Xiao et al. (2011) who also found low total carbonyl values (0.46 to 0.80 nmol/mg protein) using raw ground chicken meat. The total carbonyl results is also agreed with several studies conducted on different meat type where the values of raw meat arranged between 1-3 nmol/mg, and 5 nmol/mg protein of cooked meat, depending on several internal/external factors (Requena et al., 2003; Estévez, 2011; Sun et al., 2010). However, all supplements were showed significant ( $P < 0.05$ ) effect decreasing carbonyl formation after day 4 using both raw and cooked meat. This was in agreement with previous studies evaluation both OE and RE separately (Al-Hijazeen, 2018; Al-Hijazeen & Al-Rawashdeh, 2019). During the experimental period there were no significant differences ( $P > 0.05$ ) between both BHA and  $CM_1$  treatments of the total carbonyl means values. The antioxidant activity of RE and OE against the formation of carbonyl compounds are well documented (Estévez et al., 2005; Jongberg et al., 2013; Kumar et al., 2015; Al-Hijazeen & Al-Rawashdeh, 2019). The antioxidant mechanism of these extracts (RE & OE) are highly depends on their content of phenols. These phenolic compounds surrounding by several OH group which work as hydrogen donor, and retarding the initial auto-oxidation process (Lee et al., 2003; Estévez et al., 2005; Manassis et al., 2020). In addition, it is also correlated with the TBARS results as it agreed by Al-Hijazeen et al. (2016a, b) done previously, and several related studies (Howell et al., 2001; Lund et al., 2011; Estévez, 2011).

Furthermore, the highest significant ( $P < 0.05$ ) antioxidant effect were appeared using  $CM_3$  and  $CM_4$  additives compared to the other treatments using cooked meat samples at day 4 and 7. Overall, total carbonyl values were higher using cooked meat compared to the raw meat samples. This might be due to the

loss of the antioxidant capacity and the denaturation of meat protein during cooking (Ahn & Lee, 2002; Fasseas et al., 2008; Serpen et al., 2012). This also explains why cooked meat showed more variation between treatments compared to the raw meat in current study.

### 3.3 Meat color

Chicken thigh meat were used to evaluate the antioxidant effect, since it contain high myoglobin and lipid percentage which give better significances compared to the breast meat (Al-Hijazeen, 2014). There were no significant differences ( $P > 0.05$ ) among all treatments means values of all color parameters ( $a^*$ ,  $L^*$ , and  $b^*$ ) at day 0 of storage time (Table 3). This confirms that there were no treatments direct-effects on myoglobin chemical status or color values after mixing. This finding agreed with Al-Hijazeen et al. (2016a) and Al-Hijazeen & Al-Rawashdeh (2019) where OE, and RE additives used to evaluate its separate antioxidant effect. The  $L^*$  and  $a^*$  values were decreased significantly ( $P < 0.05$ ) during storage time (0-7 days) among all samples of control treatment. This agreed with several research studies conducted on measuring fresh meat color (Chouliara et al., 2007; Al-Hijazeen et al., 2016a; Al-Hijazeen & Al-Rawashdeh, 2019). The decrease in  $a^*$  values during storage is based on what happen through discoloration process, and the increase in met-myoglobin pigment formation (Mancini & Hunt, 2005; Keokammerd et al., 2008). The  $L^*$  values was significantly ( $P < 0.05$ ) higher using  $CM_4$  compared to the control samples at day 4 and 7 of storage (at 4 °C) time. However, there were no significant differences ( $P > 0.05$ ) appeared between all treatments additives at day 4 of storage time using  $L^*$  value. The  $CM_4$  showed the highest stabilizing effect on the  $L^*$  value of the ground chicken meat compared to the other treatments. Similar trend in  $a^*$  values appeared, and there were no significant differences ( $P > 0.05$ ) between these treatments additives. However the  $CM_4$  showed the highest effect maintaining meat color stability, and preventing their discoloration. The ability of RE and OE to maintain meat redness during storage are highly documented and well evaluated (Estévez et al., 2005; Keokammerd et al., 2008; Kumar et al., 2015; Al-Hijazeen et al., 2016a; Al-Hijazeen & Al-Rawashdeh, 2019). This anti-discoloration ability is linked

**Table 2.** Effect of adding different level of OE and RE on protein oxidation of ground chicken meat during storage time.

Time	Control	Carbonyl (nmol/ mg protein)				BHA	SEM
		$CM_1$	$CM_2$	$CM_3$	$CM_4$		
<b>Raw meat</b>							
Day 0	0.64 <sup>az</sup>	0.64 <sup>ay</sup>	0.62 <sup>ax</sup>	0.63 <sup>ax</sup>	0.62 <sup>ay</sup>	0.63 <sup>ay</sup>	0.074
Day 4	1.35 <sup>ay</sup>	0.87 <sup>bxy</sup>	0.81 <sup>bx</sup>	0.77 <sup>bx</sup>	0.73 <sup>bxy</sup>	0.89 <sup>by</sup>	0.065
Day 7	2.00 <sup>ax</sup>	1.07 <sup>bcx</sup>	0.93 <sup>cx</sup>	0.87 <sup>cx</sup>	0.84 <sup>cx</sup>	1.30 <sup>bx</sup>	0.079
SEM	0.08	0.07	0.09	0.07	0.045	0.08	
<b>Cooked meat</b>							
Day 0	1.55 <sup>az</sup>	1.45 <sup>ay</sup>	1.42 <sup>az</sup>	1.42 <sup>az</sup>	1.37 <sup>ay</sup>	1.48 <sup>az</sup>	0.05
Day 4	3.10 <sup>ay</sup>	2.63 <sup>bx</sup>	2.15 <sup>cy</sup>	1.75 <sup>dy</sup>	1.51 <sup>dxy</sup>	2.66 <sup>by</sup>	0.088
Day 7	4.60 <sup>ax</sup>	3.03 <sup>bx</sup>	2.52 <sup>cx</sup>	2.06 <sup>dx</sup>	1.70 <sup>dx</sup>	3.21 <sup>bx</sup>	0.086
SEM	0.082	0.12	0.07	0.076	0.053	0.029	

<sup>a-c</sup>Value with different letters within a row are significantly different ( $P < 0.05$ ). n=4. <sup>x-z</sup>Value with different letters within a column are significantly different ( $P < 0.05$ ). Treatments: Control (No additives);  $CM_1$ : 100 OE and 300 RE;  $CM_2$ : 100 OE + 350 RE;  $CM_3$ : 150 OE + 300 RE;  $CM_4$ : 150 OE + 350 RE; BHA: 14 ppm of *butylatedhydroxyanisole*; SEM: Standard error of the means.

**Table 3.** \*CIE Color value of ground chicken thigh meat with different level of OE and RE during storage at 4 °C.

Time	Control	CM <sub>1</sub>	CM <sub>2</sub>	CM <sub>3</sub>	CM <sub>4</sub>	BHA	SEM
<b>L*</b>							
Day 0	56.44 <sup>ax</sup>	56.19 <sup>ax</sup>	56.05 <sup>ax</sup>	56.20 <sup>ax</sup>	56.21 <sup>ax</sup>	56.31 <sup>ax</sup>	0.204
Day 4	54.51 <sup>by</sup>	55.35 <sup>aby</sup>	54.88 <sup>aby</sup>	54.99 <sup>abxy</sup>	55.52 <sup>ax</sup>	54.93 <sup>aby</sup>	0.206
Day 7	52.40 <sup>bz</sup>	53.01 <sup>abz</sup>	53.08 <sup>abz</sup>	53.52 <sup>aby</sup>	54.05 <sup>ay</sup>	53.16 <sup>abz</sup>	0.277
<b>SEM</b>	0.153	0.207	0.172	0.408	0.203	0.134	
<b>a*</b>							
Day 0	10.10 <sup>ax</sup>	9.97 <sup>ax</sup>	10.00 <sup>ax</sup>	9.77 <sup>ax</sup>	9.91 <sup>ax</sup>	10.05 <sup>ax</sup>	0.129
Day 4	8.68 <sup>cy</sup>	9.30 <sup>aby</sup>	9.48 <sup>aby</sup>	9.49 <sup>abxy</sup>	9.59 <sup>ax</sup>	8.99 <sup>bcy</sup>	0.111
Day 7	7.34 <sup>bz</sup>	8.69 <sup>az</sup>	8.84 <sup>az</sup>	8.85 <sup>ay</sup>	8.96 <sup>ay</sup>	8.47 <sup>ay</sup>	0.139
<b>SEM</b>	0.093	0.131	0.089	0.161	0.107	0.161	
<b>b*</b>							
Day 0	16.88 <sup>ax</sup>	16.98 <sup>axy</sup>	16.62 <sup>ay</sup>	16.98 <sup>ay</sup>	16.95 <sup>ay</sup>	16.78 <sup>ay</sup>	0.186
Day 4	17.28 <sup>ax</sup>	16.47 <sup>aby</sup>	16.33 <sup>by</sup>	16.60 <sup>aby</sup>	16.67 <sup>aby</sup>	16.72 <sup>aby</sup>	0.205
Day 7	17.42 <sup>ax</sup>	17.56 <sup>ax</sup>	17.45 <sup>ax</sup>	17.53 <sup>ax</sup>	17.60 <sup>ax</sup>	17.45 <sup>ax</sup>	0.116
<b>SEM</b>	0.181	0.227	0.156	0.137	0.137	0.183	

<sup>a-c</sup>Value with different letters within a row are significantly different ( $P < 0.05$ ).  $n=4$ . <sup>x-y</sup>Value with different letters within a column are significantly different ( $P < 0.05$ ). \* CIE Color L\*, a\*, b\*-value of ground chicken patties with different level of OE and RE during storage at 4 °C. Treatments: Control: No additives; CM<sub>1</sub>: 100 OE and 300 RE; CM<sub>2</sub>: 100 OE + 350 RE; CM<sub>3</sub>: 150 OE + 300 RE; CM<sub>4</sub>: 150 OE + 350 RE; BHA: 14 ppm of *butylatedhydroxyanisole*; SEM: Standard error of the means.

to their polyphenolic content as it discussed before. However, the antioxidant activity of natural RE or OE may enhance when adding them in combination (Georgantelis et al., 2007; Nieto, 2017; Sonam & Guleria, 2017).

Generally, natural antioxidant activity will increase with higher content of phenolic compounds (Kumar et al., 2015; Al-Hijazeen, 2014; Botsoglou et al., 2003). This may explain the higher effect of the combination (CM<sub>4</sub>) treatment maintaining meat color compared to the other additives. However, there were no significant differences ( $P > 0.05$ ) between the CM<sub>4</sub> and BHA treatment through a\* and L\* values at day 7 of storage time. Finally, there were no significant differences ( $P > 0.05$ ) among all treatments at day 0, and 7 regarding b\* values. In addition, b\* values were increased significantly ( $P < 0.05$ ) using all treatments (CM and BHA) levels during storage time.

### 3.4 Sensory evaluation

Among all treatments, BHA and CM<sub>4</sub> showed the highest cooked color attribute scores compared to the other treatments (Table 4). This was due to the ability of these extracts decreasing lipid and protein oxidation which affect overall meat quality and their protein functionality (Estévez et al., 2005; Al-Hijazeen, 2014; Al-Hijazeen & Al-Rawashdeh, 2019).

The spice odor was more intense in all samples of CM<sub>1</sub>, CM<sub>2</sub>, CM<sub>3</sub>, and CM<sub>4</sub> and significantly ( $P < 0.05$ ) differ from the other treatments (BHA and Control). The panelists easily distinguish the odor of these plant extracts due to their volatile compounds. However, the highest spice odor was detected in CM<sub>4</sub> treatment samples compared to the other additives (CM<sub>1-3</sub>). This connected with the effect of extracts concentration of both OE and RE among all treatments. Based on the sensory panel of the oxidation odor attribute, all treatments additives were showed lower significant ( $P < 0.05$ ) values compared to the control. In addition, CM<sub>4</sub> showed the highest effect decreasing the rancidity development and their off odor. This was in agreement with previous research studies which used different

plants essential oils as meat preservation (Al-Hijazeen, 2014; Al-Hijazeen & Al-Rawashdeh, 2019; Al-Hijazeen, 2019). The antioxidant activity of OE and RE enhances meat shelf life by retarding the aldehydes, sulfuric, and hydrocarbons compounds which are responsible on the chicken meat rancidity and their off-odor volatiles (Ahn et al., 2009). Furthermore, phenolic compounds of both OE and RE delay or prevent the formation of new free radicals during the initiation step of auto-oxidation process (Moreno et al., 2006; Keokammerd et al., 2008; Kumar et al., 2015). These finding is agreed and linked with the previous chemical analysis (TBARS and DNPH) results during refrigerated storage time. Over all, the CM<sub>3</sub> and CM<sub>4</sub> treatments showed the highest acceptability attribute scores compared to the other treatments. The positive effect of adding RE and OE on different sensory attributes had been reported in previous research studies done on different meat preparation (Thongtan et al., 2005; Al-Hijazeen, 2014; Feng et al., 2016; Al-Hijazeen & Al-Rawashdeh, 2019). Finally, CM<sub>4</sub> could be a good replacement to the synthetic BHA, and it may have superior characteristics such as flavor, anti-deterioration effect, and more consumer acceptability.

## 4 Conclusions

Adding OE and RE were showed significant ( $P < 0.05$ ) antioxidant effect when testing meat TBARS, DNPH, and color's values. Adding these extracts improves both ground meat shelf life, freshness, and their quality. However, the inclusion of CM<sub>4</sub> (150 ppm OE and 350 ppm RE) showed the highest antioxidant effect compared to the other treatments. Similar trend found by the CM<sub>4</sub> among all sensory attributes used. Generally, The CM<sub>4</sub> was the best compared to the other treatments regarding all parameters used. Overall, the combination of RE and OE could form a good promising in the future of meat industry. In addition, it could be a good natural replacement or partial substitution to the synthetic one. However, their interaction with different food system must consider for recommendation purposes.

**Table 4.** Sensory attributes means values of cooked ground thigh chicken meat.

TRT*	Sensory attributes <sup>b</sup>			
	Cooked Color	Spice Odor	Oxidation Odor	Over All Acceptability
Control	4.58 <sup>c</sup>	0.67 <sup>c</sup>	6.72 <sup>a</sup>	4.18 <sup>c</sup>
CM <sub>1</sub>	5.74 <sup>bc</sup>	4.72 <sup>b</sup>	4.82 <sup>b</sup>	6.68 <sup>ab</sup>
CM <sub>2</sub>	6.94 <sup>ab</sup>	5.60 <sup>b</sup>	4.76 <sup>b</sup>	5.99 <sup>b</sup>
CM <sub>3</sub>	6.50 <sup>abc</sup>	5.78 <sup>b</sup>	3.96 <sup>b</sup>	6.28 <sup>b</sup>
CM <sub>4</sub>	6.82 <sup>ab</sup>	7.21 <sup>a</sup>	3.76 <sup>b</sup>	8.02 <sup>a</sup>
BHA	7.77 <sup>a</sup>	0.52 <sup>c</sup>	4.22 <sup>b</sup>	6.06 <sup>b</sup>
SEM <sup>c</sup>	0.486	0.283	0.405	0.386

\*Treatments: Control: No additives; CM<sub>1</sub>: 100 OE and 300 RE; CM<sub>2</sub>: 100 OE + 350 RE; CM<sub>3</sub>: 150 OE + 300 RE; CM<sub>4</sub>: 150 OE + 350 RE; BHA: 14 ppm of *butylatedhydroxyanisole*; <sup>b</sup>Sensory attributes: Samples were evaluated on day 3; <sup>c</sup>SEM: Standard error of the means. <sup>a-c</sup>Mean within same column with different superscripts are different (P < 0.05); n=10.

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